SPREP

Pacific Islands Renewable Energy Project

A climate change partnership of GEF, UNDP, SPREP and the Pacific Islands

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The Secretariat of the Pacific Regional Environment Programme

Pacific Regional Energy Assessment 2004

An Assessment of the Key Energy Issues, Barriers to the Development of Renewable Energy to Mitigate Climate Change, and Capacity Development Needs for Removing the Barriers

TOKELAU

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our islands, our lives...

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This report is based on data gathered by a PIREP team consisting of:

Mr. Tomas Tafia, National PIREP Coordinator and local consultant

and

Mr. Herbert Wade, International PIREP Consultant

The international consultant visited Tokelau from 4-12 December, 2003. Although the original shipping schedule would have permitted the consultant to visit all three islands of Tokelau, a last minute schedule change reversed the direction of travel and only Fakaofo could be visited. The local consultant only gathered information regarding Nukunonu and Atafu.

An earlier draft of this report was reviewed by the Tokelau Government, Secretartiat of the Pacific Regional Environment Programme (SPREP), Untied Nations Development Programme (UNDP) and others. However, the contents are the responsibility of the undersigned and do not necessarily represent the views of the Government of Tokelau, SPREP, UNDP, GEF or the individuals who kindly provided the information on which this assessment is based.

Herbert Wade

September 2004

ACRONYMS

AAGR	Average Annual Growth Rate
AC	Alternating Current
DC	Direct Current
DoE	Department of Energy, Government of Tokelau
EEZ	Exclusive Economic Zone
EPC	Electric Power Corporation (Samoa)
ESCAP	Economic and Social Commission for Asia and the Pacific (UN)
GEF	Global Environment Facility
GHG	Greenhouse Gas
GMT/UTC	Greenwich Mean Time/Universal Time Coordinate
HF	High Frequency
Hp	Horsepower
kV	Kilo-Volts (thousands of volts)
kVA	Kilo-Volt-Amperes (Thousands of Volt Amperes of power)
kW	Kilo-Watt (Thousands of Watts of power)
kWh	Kilo-Watt-Hour (Thousands of Watt Hours of energy)
kWp	Kilo-Watts peak power (at standard conditions) from PV panels
LPG	Liquefied Petroleum Gas
MFAT	Ministry of Finance and Trade
OTEC	Ocean Thermal Energy Conversion
PIC	Pacific Island Country
PIREP	Pacific Islands Renewable Energy Project
PowerTok	The Tokelau power company (now DoE)
PV	Photovoltaic
SOPAC	South Pacific Applied Geoscience Commission
SPREP	Secretariat of the Regional Environment Programme
TeleTok	Tokelau Telecommunications Company
TransTok	Tokelau Marine Transport Company
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USP	University of the South Pacific
V	Volts
Wh	Watt hours of energy

Energy Conversions, CO_2 Emissions and Measurements

The following conventions are used in all volumes of the PIREP country reports unless otherwise noted.

Fuel	Unit	Typical Density kg / litre	Typical Density l / tonne	Gross Energy MJ / kg	Gross Energy MJ / litre	Oil Equiv.: toe / unit (net)	Kg CO_2 equivalent [e]	
							Per GJ	Per litre
Biomass Fuels:								
Fuelwood (5% mcwb)	tonne			18.0		0.42	94.0	
Coconut residues (air dry) [a]								
Shell (15% mcwb) harvested	tonne			14.6		0.34		
Husk (30% mcwb harvested	tonne			12.0		0.28		
Average (air dry) [b]	tonne			14.0		0.33		
Coconut palm (air dry)	tonne			11.5		0.27		
Charcoal	tonne			30.0		0.70		
Bagasse	tonne			9.6			96.8	
Vegetable & Mineral Fuels:								
Crude oil	tonne			42.6		1.00		
Coconut oil	tonne	0.920	1,100	38.4		0.90		
LPG	tonne	0.510	1,960	49.6	25.5	1.17	59.4	1.6
Ethanol	tonne			27.0		0.63		
Gasoline (super)	tonne	0.730	1,370	46.5	34.0	1.09	73.9	2.5
Gasoline (unleaded)	tonne	0.735	1,360	46.5	34.2	1.09	73.9	2.5
Aviation gasoline (Avgas)	tonne	0.695	1,440	47.5	33.0	1.12	69.5	2.3
Lighting Kerosene	tonne	0.790	1,270	46.4	36.6	1.09	77.4	2.8
Aviation turbine fuel (jet fuel)	tonne	0.795	1,260	46.4	36.9	1.09	70.4	2.6
Automotive diesel (ADO)	tonne	0.840	1,190	46.0	38.6	1.08	70.4	2.7
High sulphur fuel oil (IFO)	tonne	0.980	1,020	42.9	42.0	1.01	81.5	3.4
Low sulphur fuel oil (IFO)	tonne	0.900	1,110	44.5	40.1	1.04	81.5	3.4
Electricity								
Hydro [c]	MWh							0.25
Fuelwood [d]	MWh							0.93

Diesel Conversion Efficiency:

	litres / kWh:	Efficiency:
Actual efficiencies are used where known. Otherwise:		
Average efficiency for small diesel engine (< 100kW output)	0.46	22%
Average efficiency of large modern diesel engine(> 1000 kW output)	0.284	36%
Average efficiency of low speed, base load diesel (Pacific region)	0.30 - 0.33	28% - 32%

Area: 1.0 km^2 = 100 hectares = 0.386 $mile^2$ — 1.0 acre = 0.41 hectares

Volume 1 US gallon = 0.833 Imperial (UK) gallons = 3.785 litres — 1.0 Imperial gallon = 4.546 litres

Mass: 1.0 long tons = 1.016 tonnes

Energy: 1 kWh = 3.6 MJ = 860 kcal = 3,412 Btu = 0.86 kgoe (kg of oil equivalent)
1 toe = 11.83 MWh = 42.6 GJ = 10 million kcal = 39.68 million Btu
1 MJ = 238.8 kcal = 947.8 Btu = 0.024 kgoe = 0.28 kWh

GHGs 1 Gg (one gigagramme) = 1000 million grammes (10^9 grammes) = one million kg = 1,000 tonnes

CO_2 equiv CH_4 has 21 times the GHG warming potential of the same amount of CO_2; N_2O 310 times

Notes: a) Average yield of 2.93 air dry tonnes residues per tonne of copra produced (Average NCV 14.0 MJ/kg)
b) Proportion: kernel 33%, shell 23%, husk 44% (by dry weight).
c) Assumes conversion efficiency of 30% (i.e., equivalent of diesel at 30%).
d) Assumes conversion efficiency of 9% (biomass - fuelled boiler).
e) Point source emissions

Sources:
1) Petroleum values from Australian Institute of Petroleum (undated) except bagasse from AGO below
2) CO_2 emissions from AGO Factors and Methods Workbook version 3 (Australian Greenhouse Office; March 2003)
3) Diesel conversion efficiencies are mission estimates.
` 4) CO_2 greenhouse equivalent for CH_4 and N_2O from CO_2 Calculator (Natural Resources Canada,

EXECUTIVE SUMMARY

1. Country Context

Physical Description. Atafu, Fakaofo and Nukunonu are the three low lying island atolls that make up Tokelau's entire 12 km^2 of land area. They are located about 500 km north of Samoa. Each atoll consists of a lagoon enclosed by a curving reef on which there is a series of coral islets (*motus*), typically less than 200 metres wide, separated by stretches of reef. The highest point is less than five meters above sea level.

Population. The 2001 census found 1515 persons in Tokelau, a 7% drop from the previous census due largely to emigration to New Zealand. The census counted Atafu as having 41%, Fakaofo 34% and Nukunonu 25%. The Tokelaun population in New Zealand is about three times that of Tokelau itself. Median age in Tokelau is around 20 with six persons per household.

Environment. The environment can be considered tropical marine. Atolls are especially vulnerable to environmental damage. The water supply is easily damaged by pollutants. Land biodiversity is low. The primary dangers to the environment are tropical storms, oil spills and waste disposal from the settlements. Direct hits by cyclones are not common though near passages have caused serious damage due to high waves.

Political Development. Tokelau was first recorded by Europeans in 1765. Catholic and Protestant missionaries became active in the 1800s. However from 1863 slavers decimated the population. In 1889 the British gave Tokelau protectorate status thatstopped the practice. In 1925 the British administration was based in New Zealand (though administered from Samoa) and today Tokelau is a New Zealand dependency. Since the 1970s Tokelau has gradually become more independent although whether this will lead to svering ties with New Zealand remains a subject for debate. In 1992, Tokelau began a constitutional programme providing the dependancy with formal powers. A Tokelau Public Service (TPS) was established. The Tokelau National Government has evolved as a federation of the three islands with the basic political authority remaining with the three traditional Councils of Elders (*taupulegas*). The National Government provides only those aspects of government services that cannot be effectively provided by the *taupulega* and to transfer knowledge to the villages where needed. Elections are held every three years and the top national leader, the *ulu*, alternates amongst the three islands each year.

Economic Overview. Virtually all employment is either through the TPS or by the taupulega. There is no unemployment, and anyone over 15 can join the workforce. In 2001, 16.5% of the workforce was employed with the TPS, the rest working for the *taupulega*. New Zealand is the primary source of funds, while the sale of licenses for foreign fisheries to operate in Tokelau's Exclusive Economic Zone, a distant second. There have been unsuccessful attempts to develop a local fishing industry, but essentially ly there are no export revenues. Remittances from family members in New Zealand constitutes a major source of income for residents. Imports consist mainly of foodstuffs, clothing and fuel. All transport is by seaasthere is no airport. The *M.V. Tokelau* is owned by the government providing all shipping and passenger services to and from Samoa, and the other islands. Voyages usually run every fortnight. A trust fund is being formed to provide for recurrent expenses though there is no strategic path for growth. Private enterprise is limited to trading, though a few people provide services.

Institutional and Legal Arrangements for Energy. A Department of Energy (DoE) exists within the Ministry of PublicWorks. Electricity supply is managed by individual *taupulega* with technical support and standards provided by the department. Petroleum imports are managed by the *taupulega* through the island stores on each island. To date, all renewable energy has been developed by TeleTok (the telecommunications company) on each atoll and the University of the South Pacific (USP) at its Atafu facility. Future development of renewable energy will be coordinated by the DoE with a project in late 2004 to add 10kWp of solar capacity to the Fakaofo grid, the first to be handled by the department. There is a draft National Energy policy and associated strategy document that is being tabled for approval in late 2004 that includes strong energy efficiency measures and the long term goal of 100% renewable energy for the island group..

2. Energy Supply, Demand and the GHG Inventory

Energy Supply. Except for that part of the electricity supply to TeleTok and the USP facility provided by solar, essentially all energy is from imported petroleum. Annual imports of fuel in 2003 totalled 162 KL of diesel, 181 KL of petrol and 57 KL of kerosene. Each atoll have their households connected to the electricity grid.Usually power is provided only during peak demand periods, typically 15-18 hours per day, though 24-hour generation may be provided on special occasions. All petroleum is stored in drums. Petrol and kerosene is shipped in drums while diesel is transferred from tanks on the *M.V. Tokelau* to drums on arrival at each atoll.

The electric power system on each of the atolls is being upgraded and reconditioned with a 2004 completion date.The new diesel generators, power houses, refurbishment and distribution upgrade will provide improved reliability and a more efficient supply.

Energy Demand There remains a small use of biomass for cooking but most is now done by kerosene, Liquifeid Petroleum Gas (LPG) or electricity. Diesel fuel used by the *M.V. Tokelau* is not included in the comsumption volumes as it is refuelled in Samoa, but is easily the largest consumer. In fact all the imported diesel was used for electricity production, the petrol for outboard motor use and the kerosene for cooking. About five tonnes of LPG was imported by individuals for cooking a year.

The domestic sector is the largest consumer of electrical energy. According to the 2001 census, 90% of households own a refrigerator or freezer, 62% a video system and 57% a washing machine. Records are poor but household consumption appears to have been around 75kWh per month per household in 2003.Residents would like a 24-hour supply power with a significant increase in energy use expected if that action is taken.

Commercial use is small. TeleTok is the largest single electricity user, though earlier commercial scale fish freezers were installed on each atoll as part of a failed attempt to set up a local fishery. Currently they are not in use but if they are put back into service, they will be the largest user by a large margin. The lack of air conditioning use by government has allowed it to remain a modest user of energy.

Future Growth in Energy Demand and GHG Emissions. The present emission of CO_2 from fossil fuel use is estimated to be about 1.1 Gg per year. Growth in energy demand, assuming business the same, is expected to be nominal for all but electricity and LPG for cooking. Kerosene consumption is expected to fall in step with the rise in the use of LPG. The 10-year projection anticipates an increase of about 1.3 Gg of CO_2. If the strong measures for energy efficiency and renewable energy in the draft National Energy Plan and Strategy document are carried out, the 2013 emissions may be slightly smaller than those for 2003, with reductions improving in the following years as renewable energy investment increases.

3. Potential for Renewable Energy Technologies

Biomass. There has been no biomass resource survey. The majority of the land in Tokelau is unpopulated and densely covered with coconut trees and other woody plants so the resource is, on a per-capita basis, substantial. However to develop biomass to replace petroleum fuels for electricity generation would not be reasonable. The cost of transport of low density biomass fuels from distant islets by small boat would be high and the environmental cost too great.

Biofuel. The large volumes of coconut trees makes the potential use of coconut oil as a replacement for diesel a possible adaptation strategy for fossil fuels. Though solar power provides up to about 70% of the electrical energy needed, each additional increase supplied this way rapidly increases the unit cost. Using diesel engines running on coconut oil for the remaining 30% of electricity supply seems a reasonable approach to meeting Tokelaus goal of 100% renewable energy use. However, to do so at an acceptable cost will require careful planning and attention to the logistics of supply.

Biogas. Biogas could be a substitute for LPG for cooking if the approximately 5000 pigs and chickens were concentrated in groups large enough to make biogas generation economically feasible. This would require restructuring the way that such livestock are housed, plus the development of methods to make, collect and distribute the gas.

Solar. The solar resource is typical of Pacific Island countries (PICs) running at around 5.5 $kWh/m^2/day$ with some seasonal variation. The strength of the resource is sufficient to permit large scaleimplementation of solar energy. By using battery storage, up to 70% of electricity can can be solar powered, with the economics dependent on the cost of fuel and grant support from donors.

Solar thermal energy for water heating is economically feasible but there is currently little demand for piped hot water.

Wind. No wind data is available for most of Tokelau. A resource assessment is recommended. Given the limited land area and the fact that the land is covered by coconut trees that are of economic value as a supplier of biofuels, wind installations are likely to be best placed on the reef or in the lagoon.

Hydro. There is no hydro resource.

Wave. Wave energy conversion systems are not commercially available though there appears to be a moderate resource on the order of 20 kW/m of wave front.

OTEC. There is likely to be a large Ocean Thermal Energy Conversion (OTEC) resource but the power demand is much too small to warrant its development. Also, there are no commercially available OTEC systems.

Geothermal. There is no known geothermal resource.

4. Experiences with Renewable Energy Technologies

Solar Photovoltaics. To date, solar has been used only to provide power for communications equipment in the form of high frequency two-way radios, TeleTok satellite stations and the USP satellite station for a total of around 8kWh. In 2004, the development of an approximately 10kWp solar array with associated battery and inverter system will lead to supplementation of the Fakaofo electricity grid with PV generated power. If this trial is successful, similar PV implementation on the other atolls is expected to follow with the long range goal of development of PV to its reasonable limit for power generation.

5. Energy Efficiency Activities.

To date, there have been no energy efficiency programmes for Tokelau.

6. Barriers to Development and Commercialisation of RETs and Energy Efficiency Measures

Barriers to Renewable Energy Development include:

- as a New Zealand dependency, Tokelau has limited access to non-New Zealand capital funding for renewables;
- high access costs;
- insufficient technically trained personnel;
- lack of technical training facilities on Tokelau;
- ease of migration to New Zealand results in movement of trained personnel from Tokelau to New Zealand;
- land issues make it difficult to develop biofuels or biomass;
- the environment is very difficult for electrical and mechanical equipment;
- poor efficiency of energy use makes it difficult to economically use renewable energy to replace fossil fuels;
- access for spare parts is slow and communications with suppliers difficult;
- the extended, narrow land mass makes access to biomass or biofuel plantations difficult and expensive;
- there is a definite risk of severe weather causing damage to renewable energy installations;
- there is relatively high usage of freezers and other major appliances making the conversion to renewables more expensive on a per household basis;the country is totally dependent on imports for products and services: and
- limited knowledge at all levels of the benefits and problems of replacing fossil fuels by renewable energy.

7. Capacity Development Needs for Removing the Barriers

- Assistance is needed in the development of renewable energy and energy efficiency projects, plans and strategies.
- There is need for capacity development in the DoE for regulation and standards/guideline preparation for the energy sector.
- Technical and operational training is needed to develop and maintain DoE capacity .

- Biofuel will be a cornerstone in future renewable energy development. A biofuel delivery mechanism needs to be developed. External assistance is needed to support the development of a biofuel infrastructure.
- *Taupulega* staff need access to regular training in the local language. Tokelau needs to develop proper technical training and to build capacity.
- Development of Renewable Energy Technology (RET) certification is limited, and must be developed.
- Biofuel and wind resource surveys are needed if those technologies are to be developed in a cost effective manner.
- Information programmes targeting decision makers and the public are needed to ensure that decisions regarding RET and EET are based on relevant information.

8. Other Implications of Large Scale Use of Renewable Energy

Large scale solar energy development will need land close to populated islets, while similar sized biofuel development will need tracts of unpopulated land. Therefore land issues must be considered for both solar and biofuel development. Biogas development on a major scale will mean restructuring systems for housing pigs and chickens, and the development of biogas production, storage and delivery mechanisms.

The potential for environmental damage is small, certainly less than the potential damage that can result from the use of the fossil fuels that they will replace. The social advantages can be significant with increased energy independence, better resource use and more employment opportunities.

9. Implementation of the Capacity Development Opportunities

Co-financing opportunities are limited to development in conjunction with the New Zealand Government and the few international donors that can be accessed by Tokelau, mostly through the UN system. After 2005 there are no guaranteed energy sector projects in the pipeline. However an increasing investment in renewable energy and energy efficiency needs to happen if government energy policy goals are to be achieved. Projects that can include co-financing for capacity development are likely to be part of future energy sector activities.

TABLE OF CONTENTS

1. COUNTRY CONTEXT

1.1 Physical

Tokelau consists of three isolated low lying atolls, Atafu, Fakaofo and Nukunonu, that collectively have a total land area of about 12 km^2 . Located around 500 km north of Samoa the three atolls are located in a line running south-east to north-west. Fakaofo, the most easterly island, is 430 km north of Upolu in Samoa. Nukunonu, the central island, about 65 km to the north-west of Fakaofo, while Atafu, the north-western most island, is another 95 km further in the same direction. Each atoll consists of a lagoon enclosed by a curving reef where there is a series of coral islets (*motus*), typically less than 200 metres wide, separated by stretches of reef. The highest point is less than five meters above sea level so obviously residents are concerned about the possibility of climate change induced by sea level rise. None of the islands has a deep water inlet to the lagoon, meaning even small boat passages have had to be blasted through the reef for transit at low tide.

Approximately half-way way between Samoa and Tokelau is a fourth island, Swains Island (also called Olosenga, Olohega or Quiros). While geographically part of Tokelau it is governed by American Samoa after being settled by an American in 1858.

Figure 1-1 – Tokelau Islands

Source – CIA Fact book 2003

Atafu

Name the Duke of York Island by its first recorded European visitor, British commodore John Byron, Atafu is the smallest atoll. Its 42 islets total about 3.5 sq km, and its tiny lagoon is 17 km^2 in area. Atafu is generally considered the more conservative of the three atolls with more traditional canoes and houses – although they are being rapidly replaced by the concrete structures with metal roofs that comprise the housing on Fakaofo and Nukunonu.

Fakaofo

The last of the three atolls to be recorded by Europeans, Fakaofo was named Bowditch Island by an American expedition in 1841. Fakaofo's 62 islets include a land area of 4 km^2 and a lagoon that is 50 km^2. There are two villages on Fakaofo, Fale and Fenuafala, although they are governed by a single *taupulega* (Council of Elders). Fale has the larger population and the only boat landing for shipping, but has a smaller land area with no open land left for new housing. About two kilometres from Fale by boat, Fenuafala is not as densely populated, and is where new households are established. The school, hospital and Telecom facility are also located there. Transport between villages takes about 15 minutes by powerboat although at low tide it is usually possible to walk across on the reef connecting the islets.

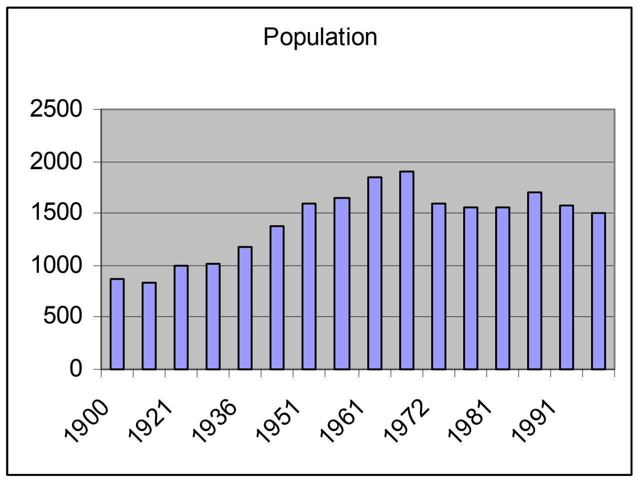
Nukunonu

The total land area of Nukunonu is about 4.7 km^2 and comprises 24 islets. It has the largest lagoon of the three islands at 98 km^2 in area. In 1791 Captain Edwards of the HMS Pandora named it Duke of Clarence Island when the British navy was searching for *HMS Bounty* mutineers. Nukunonu is the only village. .

1.2 Social[1]

Tokelau held its last census in 2001. It counted a total population of 1515 persons on island (including those working in Samoa for the Tokelau Public Service). In 1996 the total population was 1616, a 7% drop due to emigration. About three times as many Tokelauans live in New Zealand (mostly around Wellington). Today around 60% of those Tokelauans living in New Zealand were born there. In Tokelau, the median age in 2001 was around 20, a young population. The average number of persons per household was about six. The dependency ratio in Tokelau is high with 103 persons dependent (younger than 15 or older than 59) on 100 persons of working age (15-59). Note this number is solely age related as an indicator of the ratio of working age persons to the rest of the population. It has nothing to do with the actual number of persons working.

Table 1-1 – Tokelau Population 1900-1996



Source - Tokelau Population Profile, A Guide for Planners and Policy Makers (SPC 1998)

Atafu is the most populous atoll with a 2001 Tokelauan population of 588 (41%). Fakaofo with 479 (34%) was second and Nukunonu had 361 (25%). The remaining 87 are residing in Samoa but are part of the public service.

A slowly declining population indicates a continuing emigration trend to New Zealand. Since the 1972 census the population has been relatively constant and the population in 2004 is estimated to be around 1500 persons.

About 55% of the population over 15 do not have a school certificate but the percentage of certification is much higher in the younger segments of the population and the average level of education is rising over time. School is compulsory from age 5- 15. A school to form 4 (usually 16-year olds) is located on each atoll. A boarding school that runs to form 5 and serves all of Tokelau is located in Fenuafala on Fakaofo.In 1996, 83% of 16-year olds and 58% of 17-year olds attended school. Aside from the University of the South Pacific distance education facility on Atafu, tertiary education is available in Fiji and New Zeland for those who qualify for scholarships.

[1] *Tokelau Population Profile, A Guide for Planners and Policy Makers - Based on the 1996 Census*, Secretariat of the Pacific Community 1998

In 1996, 63% of the population considered themselves as Protestant (Congregationalist), and 35% as Catholic. A small community (2%) of Jehova's Witnesses is also present. In 1996, around 98% of Atafu residents were Congregationalist while 94% of Nukunonu were Catholic. Fakaofo had 76% Congregationalist and 21% of residents stating they were Catholic.

Social unions are stable with less than one percent of the population in 1996 stating they were divorced or separated. Generally, there is little migration between the islands.

1.3 Environmental

The south-east trade winds blow from March to October. From November to March they tend to be variable although generally northerly and ranging from calm to cyclone strength. Cyclone passages have been recorded in Tokelau although they are unusual so far north. In 1990, Cyclone Ofa passed south of Tokelau but caused considerable damage due to King tides.

Rainfall may exceed 2500 mm each year, and tends fairly evenly distributed November to March are the most likely dry spells. Extended droughts are rare but have occurred.

Atolls are especially vulnerable to environmental damage. Fresh underground water supply is easily accessed by pollutants, both chemical and biological, and loss of portability due to encroachment by sea water is a common result of over pumping the supply. Land based biodiversity is low and the introduction of disease or invasive species would be a serious problem.

A real danger for the atoll environment is from petroleum spills caused by poor handling, leaking containers, engines and other machinery. On land, oil spills can damage the water supply and land based ecosystems. Spills on the reef sea life may cause pollution and disrupt local s fishing patterns.

Household waste disposal also presents a problem. The approach differs on the islands but a high percentage of food waste is used either for compost or animal feed.

Other wastes are often dumped in open areas on uninhabited islets. . Nukunonu and Atafu have an organized waste collection system but Fakaofo households are individually responsible for their own waste disposal. Most solid waste is disposed of on an unpopulated islet, burned or buried. Tokelau has no sewage systems. Fakaofo mainly uses household septic tanks with flush toilets. Atafu and Nukunonu still have many "over water" toilets where wastes are dumped into the lagoon.

1.4 Historical and Political[2]

The first recorded European visit was by British Commodore Byron (the grandfather of the famous British Poet, John Byron) in 1765. Byron sighted Atafuwhich he named "Duke of York Island". Nukunonu was first sighted by a British warship in 1791 while searching for mutineers from the *HMS Bounty* and named Duke of Clarence Island but it was not until1835 that Fakaofo, the most populated island, was sighted.

[2] The primary reference for this section is *Report of the Administrator of Tokelau for the period ended 30 June 2002*, L.J. Watt, Administrator of Tokelau, Ministry of Foreign Affairs and Trade (MFAT), various internet sources for historical information and local interviews.

Nukunonu was converted by Catholic missionaries based on Wallis Island (Uvea) between 1845 and 1858. Atafu was converted to Christianity by a Samoan teacher from the London Missionary Society who arrived in 1861, and is almost entirely protestant. Fakaofo was originally Protestant but later accepted Catholic missionaries as well. Today Fakaofo has both Catholic and Protestant churches.

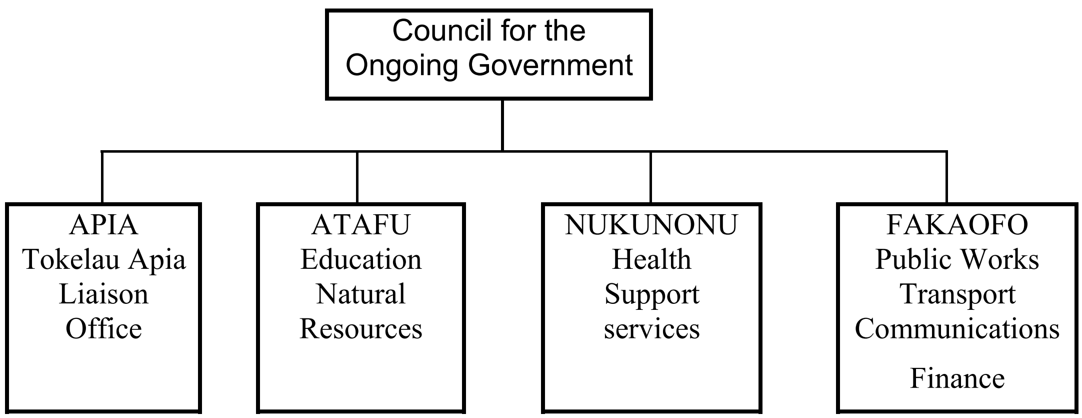
Until 1863, most European contact was friendly and mutually beneficial. However in that year the Peruvian slaving ship *Rosa Patricia* called into Tokelau followed by several other "Blackbirders" who decimated the population. Missionaries estimated the population before the raids to be 541, with 261 on Fakaofo, and 140 on Nukunonu and Atafu. After the Blackbirder's departure, the total population of Tokelau appears to have been under 250, mostly women, the very young and very old. Virtually all able-bodied men had been taken away. The repopulation was largely by immigrants marrying the Tokelau women. These included other Polynesian nationalities, Portuguese, German, Scottish and French making Tokelau one of the most genetically diverse of the island countries.

Tokelau's three islands became a British protectorate in 1889, partly to protect the islands against futher raids and because they expected to use the islands as staging posts for the planned trans-Pacific telegraph cable. Until 1916 the islands were administered from various locations including Fiji, Samoa and Tonga. From 1916 - 1925 they were administered from phosphate rich Ocean Island (Banaba) as a part of the Gilbert and Ellice Islands protectorate (now Kiribati and Tuvalu). In 1925, the administration was shifted to Samoa, then time a New Zealand territory.The name "Tokelau" became official in 1946, and in 1948 Tokelau officially became a New Zealand territory administered from Samoa. Since the 1970s Tokelau, with United Nations (UN) support and guidance, has become increasingly independent politically, although full independence is still a subject of debate. In 1992 New Zealand and Tokelau reached agreement on a constitutional programme to provide Tokelau with formal powers to establish and operate its own national government. The persons employed in administration became members of the Tokelau Public Service (TPS) and a number of departments that had been located in Samoa were moved to Tokelau such as health and education. Remaining in Samoa are departments that interface between Tokelau and the outside world until better communications, reliable power and easier access is available locally.

In developing a new national government, the need to provide general public services and a tendency to organize itself along New Zealand systems resulted in a national focus that many Tokelauans felt eroded traditional authority and the power of village leaders. This was seen as an authority separate from their own people call of the people was to "Bring the services back to where the elders are and where the authority is."

By 2004, government had evolved into a combination of traditional Tokelauan and western styles called the "Modern House of Tokelau." A draft Constitution embracing that approach had been prepared. At the base is the traditional authority, the *taupulega* (Council of Elders), consisting of about 20-35 persons on each atoll. Each atoll has it own specific manner of selecting the persons on the *taupulega*. On Atafu and Nukunonu there is a family head, much like the *matai* (chief) of Samoa, who becomes a member. On Nukunonu females and males can become *matai*. On Atafu, only males can be *matai*. On Fakaofo, all persons over 60 can be members and new members are chosen by existing members to fill vacancies. The *taupulega* is the ultimate source of authority. As the primary governing unit, it runs all services on island and provides employment for individuals wishing to have a cash income. Funds for the *taupulega* are allocated by the national government on an annual basis with no real restrictions on how it is spent. The non-traditional government exists side by side with the traditional. The National Government exists primarily to advise the traditional government, to inter-face with the outside world and to provide information so the elders can make informed decisions. The three pillars of the Modern House of Tokelau are: re-empowering the elders, strengthening the villages as the foundation of the territory and economic development to return to a spirit of self-help and self-reliance. . The National Government provides only services that cannot be provided by the individual villages; and to transfer knowledge and capacity to the villages as needed.

Figure 1-2 – Organisation of the Tokelau Government as distributed by island



On the non-traditional side, each island has an elected mayor, the *(pulenuku),* who is automatically a member of the *taupulega*, a *faipule* who is elected as the atoll head of government and elected members of the National Fono, the single house legislature. The post of *Ulu o Tokelau* (head of the National Government) rotates among *faipule* yearly. So the 2003 *ulu* was from Fakaofo, in 2004 the *ulu* Atafu and so on. The Nukunonu *faipule* will serve as the *ulu* in 2005. The *ulu* chairs the Council for the Ongoing Government whereas the Chairman of the General Fono is selected by the *fono* (meeting).

Elections are held every three years with all citizens over18 voting on Atafu and Fakaofo and those over 21 voting on Nukunonu. Before 1999, only *faipule* and *pulenuku* were elected to the General Fono but since then all delegates to the national *fono* have been elected. Membership in the General Fono was gradually reduced from 45 to 27 to 18 (6 from each atoll). In the January 2002 elections the General Fono adopted a population related representation. Atafu was allowed eight members, Fakaofo seven and Nukunonu six. The General Fono meets in three sessions of 10-12 days each during the year, rotating through the three atolls.

During the time between General Fono meetings, the three *faipule* and the three *pulenuku* (mayors) meet as the council for the Ongoing Government and provide continuity of National Government. The *faipule* is a key person for each atoll as that position is effectively the broker between the villages and the outside world and the Council for the Ongoing Government is the key structure making the tie between the traditional governing structure of the village and the National Government.

1.5 Economic

Virtually all employment in Tokelau is through the TPS or the *taupulega* on each island. There is no unemployment. Anyone over 15 can join the casual workforce of the *taupulega*. In 1996, 89% of men and 66% of women of working age considered themselves employed this manner. Since 1994, the *taupulega* has increased in importance as an employer and has taken over many of the casual and previously unpaid TPS workers. In 1996, 44% of households had at least one member with a TPS salary and 60% had at least one person working with the *taupulega* work force. In 2001, 16.5% of the population over 15 was a member of the TPS. Senior citizens (over 60) receive a small pension (NZ$27.50 per month in 1996). Thirty five percent of households have at least one person in this age group. Unlike some PICs, remittance incomes are minor as are revenues from selling handicrafts, produce, copra, animals or fish.

The primary non-donor financial source is the sale of licenses for foreign fisheries to operate in the Tokelau Exclusive Economic Zone. In 2001 that amounted to nearly NZ$1.6 million. There are no taxes on income or sales but an import tax is imposed on some goods and for 2001 generated NZ$312,920 of revenue for government. Boat fares and freight brought government NZ$297,477 in revenues.

The traditional Tokelauan house has all but disappeared with only 10 counted in the 2001 census. The housing is mostly with a concrete floor, a wall and a metal roof, although some wooden houses remain. New houses are of a standard concrete design with a metal roof.

Water supply is almost exclusively through rainwater catchments. Over 90% of houses include water tanks receiving runoff from metal roofs. All new houses that are built include a large water tank and metal roof. Households who do not have a water tank typically share with other households, there is little use of wells although a fresh water lens is available.

If a new family needs a house, land is allocated by the village and a new home costing NZ$20,000 home is provided free. New houses are of uniform design, concrete in construction with wood trussed roof having hurricane strength attachments and corrugated steel cover. All new homes include a large concrete water tank under the floor that is fed from the roof.

Cooking in 2001 was mainly with (62% of households) kerosene with 19% using gas, up from 7% in 1996. Thirteen percent of households use the traditional Tokelauan *umu* (underground oven) and 3 of the 241 households reported fuel wood as their primary cooking fuel.

Lighting is electric although some kerosene lanterns remain in use for power outages and after the power is switched off at night.

1.5.1 Tokelau accounts

As a dependency of New Zealand, the only financial information is in the form of national accounts. The latest audited accounts available to the mission were for 2001 and those are reproduced from the Report of the Administrator of Tokelau for the period ending 30 June, 2002 as Table 1-2.

Table 1-2 – Tokelau Accounts (Thousands of NZ$)

Item	Fiscal Year	
	2000	2003
NZ Budgetary Assistance	**4,800**	**4,750**
LOCAL REVENUE		
EEZ Fees	860	1,900
Interest	95	133
Duty	317	274
Coins and Stamps	5	0
Community Service Levy	182	330
Boat fares and Freight	116	311
Other Revenue	447	92
Total Local revenue	**2,022**	**3,040**
TOTAL REVENUE	**6,822**	**7,790**
EXPENDITURES		
Administrative services and supplies	1,380	1,094
Office for the Council of Faipule	803	1,274
Transport	1,174	1,485
Education	948	1,138
Health	657	1,021
Natural Resources and Environment	86	96
Public Works	216	370
Atafu	604	778
Fakaofo	547	685
Nukunonu	509	611
Doubtful Debts	-19	n/a
TOTAL EXPENDITURES	**6,905**	**8,552**

Source – Report of the Administrator for Tokelau (2003)

1.5.2 Imports and Exports

Commercial fishing has been promoted for Tokelau by regional organizations for several years, even to the point of providing small catamaran fishing boats for open sea fishing, installing fish processing areas and expensive flash freezers on each atoll. However the freezers are not used and the boats are beached.

Essentially there are no exports. Even taro and bananas are often imported from Samoa.

Government imports are included as expenses in the national accounts. Since there are no private businesses importing goods all imports are either for government or household use. Domestic imports consist mainly of foodstuffs, clothing, goods and fuel. Each island has its own accounts. To obtain information regarding domestic imports, the shipping sheets from the island store have to be obtained and analysed. Because the *M.V. Tokelau* changed its routing, only Fakaofo was visited by the mission. However, there is no reason to believe that the imports to the other islands are substantially different. There are no records of other individual imports such as appliances,

Table 1-3 - Fakaofo domestic imports 2002

Consumer Imports 2002-Fakaofo		Per HH/mo
Outboard Engine Oil	$3,285.82	$3.04
Kerosene	$10,593.78	$9.81
Petrol	$44,345.43	$41.06
Cigarettes	$28,773.09	$26.64
Alcoholic Drinks	$16,749.47	$15.51
Soft Drinks	$18,755.44	$17.37
Food	$338,074.27	$313.03
Household goods	$68,610.78	$63.53
Clothing	$15,643.56	$14.48
Mechanical parts	$1,740.85	$1.61
TOTAL	$546,572.49	$506.08

Source – Fakaofo Island Store Import Records

LPG and goods bought abroad and shipped to Tokelau.

A trust fund is being formed to provide for recurrent expenses as has been done in Tuvalu. As of 2004, the fund contained NZ$6.4m dollars but there is no specific path for its.

1.6 Institutional Context for Energy

There is no formal energy office although the Public Works Ministry on Fakaofo has energy as part of its portfolio. The DoE Director on Fakaofo and the individual island power system operators handle matters of electricity supply. Petroleum imports and distribution are handled by the three island stores. Although to date all renewable energy activity (other than the little remaining traditional biomass use for cooking and copra drying) has been by TeleTok and USP, the DoE Director as the senior person with energy technology experience is by default the focal person for public renewable energy and energy efficiency projects.

There is no legislation specific to electricity supply or energy in general although there is a 2003 set of health and safety rules for Tokelau that covers electricity and gas work. Those rules confirm that the New Zealand standards for electricity, gas and dangerous goods are applicable in Tokelau and make the Director of Public Works responsible for their enforcement. The rules also provide for fines and prosecution should the rules be violated. These rules include petroleum storage but specifically cover only basic labelling requirements and establish a no-smoking zone around flammable goods storage. References to storage conditions are vague and non-specific.

1.6.1 Energy Policy

At the request of the Council for the Ongoing Government, UNDP has funded technical assistance for the development of a Tokelau energy policy. A draft has been prepared by a consultant and has been tabled for debate. The primary focus of the policy is the desire of Tokelau to become self-reliant in energy through a combination of renewable energy and energy efficiency measures. The three *taupulega* and the Council for the Ongoing Government recognize the risk associated with being so strongly dependent on imported petroleum and have requested that the policy to be developed focus on the long term goal of 100% renewable energy.

2 ENERGY

2.1 Energy Supply

2.1.1 Petroleum

Petroleum is ordered by the government store on each atoll based on existing inventory and expected demand. Fuel is purchased from Samoa distributors under tendered contract and, except for diesel is shipped in 200 litre steel drums. Diesel is carried in tanks on the *M.V. Tokelau* and pumped into drums on arrival. All fuel storage is in drums.

Because fuel drums are not supposed to be shipped at the same time as passengers, special fuel voyages are made periodically when petrol and kerosene shipments are needed. This happens about every 8-12 weeks.

Prices on Tokelau are set by the government store, essentially as a fixed mark-up over cost. Storage is indoors and drums are protected against the elements. A storekeeper pumps fuel into personal containers after it has been purchased. Fuel storage in Fakaofo is at Fale village, but only a few metres from habitation, and represents a definite hazard. Consideration is being given to landing and storing fuel on Fenuafala, particularly now that all electricity generation is to be on Fenuafala and the bulk of the diesel fuel will be used there.

Store records of petroleum imports to Fakaofo were analysed for 2002 (the last complete year at the time of the site visit in 2003) and the DoE Director obtained petroleum import information for Atafu and Nukunonu for the latter half of 2003. There is no reason to believe there was any significant change in petroleum use from 2002 to 2003 on Fakaofo since the new generators have not yet been placed into operation. So the estimated petroleum use for 2003 uses 2002 data for Fakaofo.

Table 2-1 – Estimated fuel imports calendar year 2003

Atoll	Diesel Fuel Litres	Petrol Litres	Kerosene Litres	Outboard Motor Oil Litres
Atafu	62000	42000	19000	n/a
Nukunonu	52800	59563	18981	1309
Fakaofo	47000	79800	19200	400
TOTAL	159,800	181,363	57181	1709

Source – DoE Director (Atafu and Nukunonu) and Fakaofo Island Store

There is no accurate data available for prior years to determine a trend for petroleum imports.

Essentially, all diesel fuel is used for electricity generation, all kerosene for cooking and all petrol for outboard motors. The substantially lower diesel fuel consumption on Fakaofo is maybe due to the higher electricity tariff ($0.50 vs $0.30 and $0.35) there. The much higher use of petrol in Fakaofo is the result of boat traffic between Fenuafala and Fale. LPG is imported in cylinders by individuals. Records of LPG imports are not kept but about 50 homes use five tonnes of gas a year for cooking. Empty cylinders shipped back to Apia .

Problems with power quality and reliability have plagued Tokelau since the initiation of organised power delivery in the 1980s. This has been largely due to the limited technical capacity on the islands, that required servicing for anything other that the basic problems to come from Apia. Also the harsh environment causes equipment problems with electronic controls and the alternators. By the 1990s, the power system on each atoll consisted of a powerhouse with one or two diesel generators delivering three-phase power into a low voltage underground distribution system. In 1993 the New Zealand Ministry of Foreign Affairs and Trade (MFAT) commissioned a review of the power system and provided recommendations. In 1996 the Electric Power Corporation (EPC) of Samoa was contracted to prepare a more comprehensive design for the improvement of the entire power system. That study proposed central generators on each atoll, with an 11kV distribution system and a series of transformers to connect loads. The EPC engineers determined the peak load at about 28 kVA per island and listed many problems including an environment that is unusually hostile to electrical and rotating machinery.

Because of concerns regarding sustainability, MFAT followed with another study in 1997. In that study, New Zealand based Design Power Ltd prepared a *"Master Plan for Tokelau Electricity System"* that reviewed the *ad hoc* development of the electric power sector and outlined an approach to its upgrading and improvement. This included a shift from 12 to 24-hour power. Both diesel and solar power were considered with diesel the choice due to capital cost considerations. Design Power estimated peak power in 2007 at somewhere between 30kva and 70kva for each island according to the use of air conditioning and electric cookers. Based on these load forecasts, an energy requirement of about 420 kWh/day was projected. To supply that, they estimated a 900 m^2 solar array charging a 4,500 kWh storage battery would be adequate. The cost was estimated at N.Z $1.3m dollars per island.

Other studies were commissioned with further reports in 1998 and 1999 essentially confirming the design concept provided by the 1996 EPC study. . In late 2000, Tokelau engaged PBPower of New Zealand to undertake the detailed design and commence construction with a budget of N.Z$1.5 million. At the time of commencement, each village has a single 45kVa generator ranging from 6- 18 months old. The Atafu system upgrade was commissioned in 2002 though synchronization of the two generators was not yet possible. The Nukunonu system was made operational in 2002 with some details still outstanding. Fakaofo with its more complicated two village system was integrated into a single power station on Fenuafala and an 11kV submarine cable to connect Fale village to the system. Fakaofo remains incomplete as of early 2004 but should be commissioned later in that year. Thus at the end of 2004 an upgraded system with a new power house, multiple diesel engines capable of being paralleled, new 11kV distribution and refurbished low voltage distribution will be in place on each island. Actual total cost as of late 2003 was about NZ$2m dollars including inputs from Tokelau.

Completion was originally scheduled for mid-2002 but actual this will now be mid-or late 2004. Much of the delay in Fakaofo was related to land tenure issues for siting the powerhouse due to "protracted discussions from N.Z. family members[3]" that kept powerhouse construction from starting before mid-2003. Because the currently unused fish freezers on each island represented a load comparable to the entire remaining power system load, the Iveco generators that were installed with the freezers remains dedicated to the freezers though they can be used for supplementary power for the power grid. In Fakaofo the Iveco generator remains with the freezer in

[3] *Tokelau Power Project Project Completion Report as of 20 December, 2003*, PB Power 2004

Fale to provide a local power system backup should there be a fault in the submarine cable from Fenuafala.

Spare parts remain a problem. Even before the new generators were put into service, most of them had parts, mainly electronic controls, stripped from them to repair the old generators. The freezer engines are Italian Iveco units and for reasons not given, the new power system engines are made by Cummins while the older ones are Perkins engines. This compounds the spare parts provision with three different brands of engines now operating for power production in Tokelau. No spare parts were included in the rehabilitation project and no recommendations given for their purchase by DoE.

Table 2-2 – DoE cost structure

	Fakaofo	Nukunonu	Atafu
$ per kWh (without capital inclusion)	$1.02	$1.30	$1.82
Tariff	$0.50	$0.35	$0.30
Meters	73	83	116
Domestic no meters	17	14	4
Taupulega no meters	13		
Churches no meters	3	5	1
Workers at $1.95/hr	3	5	1
Jan-April 2003 consumption kWh	30,614	28,494	39,191
Income/mo	$4,255	$2,493	$3,429
Average cost of fuel and labour per month	$7,797	$9,268	$8,124
Operating subsidy per month	$3,542	$6,775	$4,695
4 month budget for repairs	$26,700	$20,000	$20,000
Average kWh cost per customer for fuel and labour	$1.05	$0.86	$0.85

Source - DoE

An independent review of the project funded by the U.N. in 2004 indicates that the primary lesson learned in the project was that the capacity of Tokelau to carry out a project of this magnitude is very limited and time and money must be allocated to overcome that limit. The project went up against limits of technical capacity, labour institutional capacity and access capacity. To overcome them has required twice the expected time and a 25% increase in cost, even though the original estimates included added time and cost in expectation of these problems.

In reality the project was three projects, one for each atoll, with individual difficulties and needs. For any project in Tokelau, it will not be a national project but three projects and there should be little expectation of carryover from one to the other.

Figure 2-1 – Power system components in place (late 2003)

Component	Atafu	Nukunonu	Fakaofo (incomplete)
11kV-400V substations	5	4	4
HV Cable (metres)	920	780	3430
LV Cable (metres)	6750	4750	14300
Pillar Boxes	48	33	38
Customer meters	100	85	90
Generators	2	3	1
Power house	1	1	1
Covered fuel drum store	1	1	1

Tokelau Power Project Project Completion Report as of 20 December, 2003, PB Power 2004
Not included are the generators assigned to the fish freezers that can provide backup capacity.

Department of Energy

In 2002 a central power authority, the Department of Energy, was formed with the long term goal of establishing technical and procedural standards, formal training processes, and increasing the operational and business management quality of electric power generation in Tokelau. An experienced expatriate manager, formerly General

Manager of the Tuvalu Electric Corporation, was hired to establish the structure of DoE and develop procedures, regulations and training processes for the organization.

The manager of DoE is based on Fakaofo but operational management remains with each *taupulega* including hiring of staff. DoE has authority in safety matters and technical standards and sets overall policy and procedures but has limited enforcement powers and only two staff, one who is an expatriate under a limited term contract with localization likely by 2005. With the power system broken into three distinct and nearly equal components and with transport between islands limited and schedules inconvenient, forming a central power authority has been difficult, and will take time to become fully established. To date, DoE has mainly been functioning as an interface between Tokelau and the power system upgrade contractor, checking on work and ensuring that the installed system meets the needs.

Individual *taupulega* set prices so each atoll has its own tariff structure. All have a flat rate tariff with Atafu at $0.30 per kWh, Nukunonu $0.35 and Fakaofo $0.50 far below the real cost of production. The lower per-capital diesel fuel use on Fakaofo appears to demonstrate user sensitivity to tariff levels though other factors may be involved. Actual generation costs have been estimated by DoE to be between $1.02 and $1.82 per kWh just for operations. There is no formal regulatory process other than technical and safety oversight from DoE. New Zealand standard electricity regulations 1997, SR 1997/60 and amendments are the basic standards used.

Power is usually unavailable 24- hours a day. Normal hours are from 0600-1500, 1800-2300. If a special event such as wedding or funeral requires longer hours, it can be arranged with the *taupulega* for a fee sufficient to cover the added labour and fuel cost.

2.1.2 Renewables

Institutional Structure

There is no specific institutional structure for renewable energy development or use. Each renewable energy development in Tokelau has been done in isolation by the institution receiving the benefits. Since there is 100% electrification by the grid and almost no demand for piped hot water by households, there is little opportunity for renewable energy use by individual households. Therefore almost all renewable energy development has been and is expected to continue to be done by institutions such as TeleTok, DoE and USP.

With the limited capacity in government to develop and manage renewable energy projects, this approach appears reasonable and more likely to result in user satisfaction and proper maintenance than centralizing renewable energy development under a single government ministry. By each institutional entity having to develop the human resources necessary for system maintenance, the approach helps develop a larger pool of technically trained persons for the future than centralized management of all renewable energy implementations. Where there is a need for development of renewable energy systems for public use, such as navigational aids powered by solar energy or solar powered street lighting for operation after generation is stopped, DoE appears to have the technical capacity to handle these miscellaneous renewable energy installations.

Developing the capacity for biofuels and biogas, the most likely biologically based technologies for Tokelau, will require cooperation by several organizations since personnel responsibility for land tenure, transport, energy, forestry and agriculture all have to be involved.

Technologies

Currently, solar is the only renewable energy technology used in Tokelau other than biomass for some cooking.

Regulation

Although in theory all regulations relating to renewable energy in New Zealand also apply in Tokelau, only the locally prepared Electricity, Gas and Dangerous Goods Rules are likely to have any level of enforcement. Their enforcement is, by default, handled by DoE.

2.2 Energy Demand

2.2.1 Petroleum

Land Transport

With the very compact villages, land transport consists of moving materials by truck from the wharf to storage, and from storage to use points. The very small amount of diesel fuel used for the two trucks per island is not documented. There are no private vehicles in Tokelau.

Marine Transport

The primary user of transport fuel is TransTok, operator of the *M.V. Tokelau.* Annual consumption in 2003 was 360,000 litres, about 12,000 litres per voyage. This fuel is purchased under a contract that is renegotiated on a annual basis.

All petrol is used for private boats. The 2001 census counted 153 outboard motors in Tokelau to power 148 boats, almost all of aluminium construction. Fakaofo with two villages separated by water has the highest concentration of power boats at 68 boats for 80 households (85%), Nukunonu with 38 boats for 66 households (58%) and Atafu with 42 power boats for 83 households (51%). There is no commercial use of fuel other than diesel for the *M.V. Tokelau* which as not been included in the analysis as it is international shipping. On Fakaofo, petrol sales are often rationed to 20 litres per fortnight per *inati* (family group) to maintain some control over usage and to distribute the limited fuel supply equitably. Even with rationing sometimes sales have to be stopped before the next shipment arrives to ensure an emergency supply of petrol is available.

Air Transport

There is no air transport

Electricity Generation

Diesel is delivered on every voyage of the Tokelau in its fuel tanks. On arrival it is pumped into drums for shifting to shore then transported to the generator site.

Household Lighting and cooking

Although some kerosene use for lighting remains for illumination during the night hours that the generator is not operated, the amount is small. Cooking is the primary use of kerosene and it is being replaced by LPG. Currently, all LPG is used for cooking.

Table 2-3 – Appliance Survey – Fakaofo and Atafu

Item	Ownership		
	Average Watts	% Atafu	% Fakaofo
Incandescent Lights	60	15.5%	14.3%
Fluorescent Lights	160	98.8%	96.4%
TV/VCR	120	54.8%	39.3%
Stereo	40	21.4%	35.7%
Fan	40	97.6%	17.9%
Computer	50	11.9%	17.9%
Printer	40	4.8%	10.7%
Play Station	10	2.4%	10.7%
El Guitar	50	1.2%	3.6%
Amplifier	500	1.2%	3.6%
Refrigerator	130	23.8%	35.7%
Freezer	230	90.5%	75.0%
Sandwich Maker	700	19.1%	21.4%
Electric Frying Pan	800	14.3%	21.4%
Microwave	300	1.2%	3.6%
Rice Cooker	500	2.4%	35.7%
Stove	1000	3.6%	7.1%
Iron	1350	9.5%	21.4%
Washing Machine	80	63.1%	39.3%
Water Cooler	200	4.8%	7.1%
Kettle	2200	69.1%	32.1%
Battery Charger	40	1.2%	0.0%
Power Tool	150	88.1%	71.4%

Source – DoE

2.2 Electricity Domestic

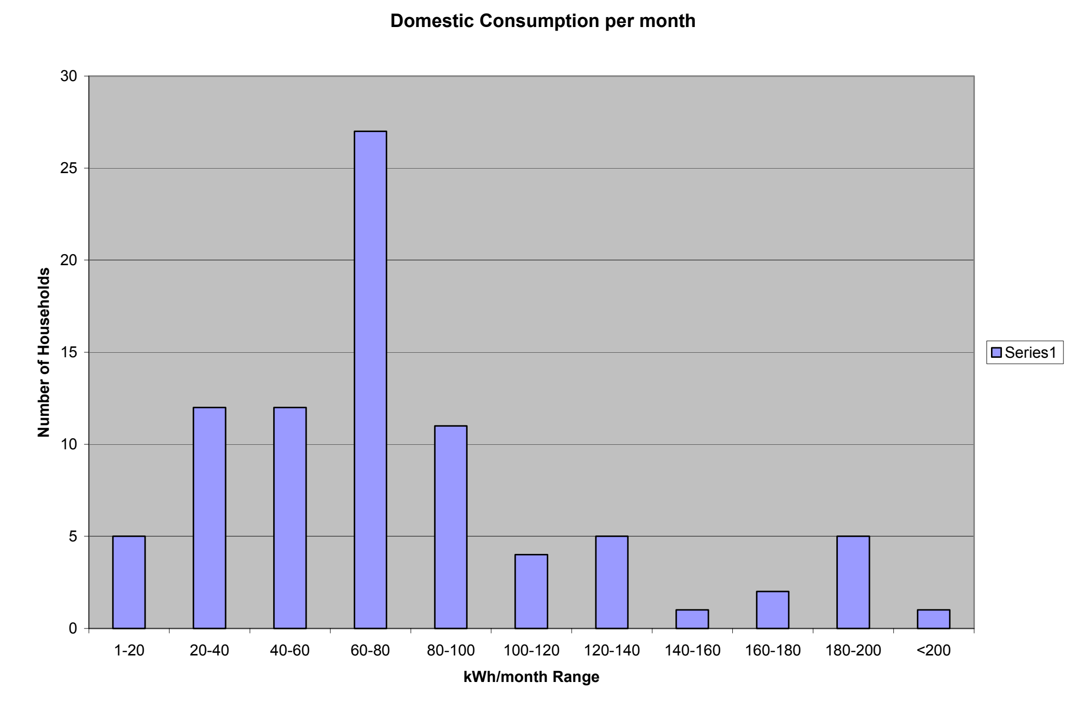
The use of refrigerators and freezers and of video systems has increased dramatically in the past 10 years and these, rather than commerce or population growth, have been the main reasons for increasing demand for electrical energy in 2004. In 2001, 90% of households owned a refrigerator or freezer and 62% owned a video system. About 57% of households in 2001 had a washing machine and about 74% owned a radio. At one time some electric cooking stoves were imported but their very high demand could not be met by the small power systems and their use is effectively banned.

In 2003 a household appliance survey was carried out by DoE on Atafu and Fakaofo yielding the information shown in Table 2-3.

An analysis of Fakaofo domestic consumption included 84 customers with working meters. Their usage pattern is shown in Figure 2-2. Domestic use averaged about 75 kWh/month during 2003. Although detailed billing records were not available for Atafu and Nukunonu, partial records indicated similar consumption patterns though at slightly higher levels.

In the future if the power system shifts to 24- hour power, time of use will increase 10 hours (a 70% increase) and about a 50% increase in energy use can be expected with the existing mix of appliances due to the longer operating period for refrigerators and freezers. Experience in Rakahanga (Cook Islands) with a shift from 12 to 24 -hour power (100% increase in time) caused about a 75% increase in energy use with a similar appliance mix.

Figure 2-2– Domestic Customer Use Patterns (2003 Fakaofo data analysis)



Source – DoE Fakaofo customer billing records 2003

Commercial

A large flash freezer and storage freezer has been installed on each atoll as part of a commercial fishing project that has failed. The freezers are unused but have their own dedicated diesel generator, which, though still available to operate the freezers has been made available to the power system as a supplement and backup. Although there have been repeated discussions regarding again trying commercial fishing from Tokelau, it does not appear to be a sustainable enterprise that is likely to provide a net input to the local economy.

Commercial use of electricity is limited. TeleTok is currently the largest electricity user on each atoll, but should the fish freezers be put back into service the freezers would become the largest. Commercial customers include TeleTok, hospitals, schools and stores. None used more than 1000 kWh/month, and most were in the 400-800 kWh/month range. Much of the TeleTok load is supplied by solar energy with the grid providing the rest.

Government

Government use is modest and comparable to domestic use. Electricity is almost entirely for lighting, office machines and computers although a few offices have fans. No air conditioners are used and the present policy is not to install them.

2.2.2 System Demand

Peak power occurs when the generator is first loaded after having been shut down for several hours. This is the result of all refrigerators and freezers staring simultaneously. The peak on each island is typically 30-40kVa. If the systems are operated on a 24-

hour basis, the peak is lower since the refrigerators and freezers then load randomly. Two days of 24-hour power were tried during the site visit to Fakaofo but results were inconclusive due to problems with inconsistent logging of power levels by the Fale operator. Peak loading for Fenuafala during the period was 14 kVA. For Fale it was approximately 20 kVA. Note that when the two power systems are combined the two peaks will not necessarily be additive. Peak demand on Atafu and Nukunonu is each less than 30 kVa. Clearly the 24-hour peak is in the evening but its exact value could not be determined from the recorded data.

2.3 GHG Inventory

2.3.1 Carbon Dioxide

Population is not expected to grow significantly over the next ten years. Kerosene use is expected to decline in favour of LPG. Twenty-four hour power is likely to be the case within 10-years increasing consumption by about 50% (4% AAGR) if solar energy is not installed to offset fuel use. Energy efficiency measures should stop the growth of petrol use and if aggressively applied should provide a reduction.

2.3.2 Opportunities for Reduction

Energy conservation for boat use and electricity energy efficiency improvements offers the greatest opportunity for immediate GHG reduction. Limiting outboard engine size and increasing petrol prices above a certain minimum purchase level could work to reduce petrol use. An analysis should be made of the fuel efficiency and cost effectiveness for small diesel outboard engines to see if incentives for their purchase should be provided. Encouraging the return to the use of sailing canoes for subsistence fishing could dramatically reduce petrol use.

Up to 2014, distillate use for electricity generation is expected to grow at about 4% per year due to increased hours of supply. Electricity energy efficiency measures should also be examined particularly with regard to improving the efficiency of refrigerators and freezers.

Table 2.4- Petroleum imports for 2003, GHG production and projections for 2013

	2003						2013			
Fuel	KL	KT	TOE	GHG (t)	GHG (Gg)	% of GHG	AAGR	KL	GHG	% of GHG
Motor Spirit	181	132	144	454	0.5	*43.0%*	0%	181	0.5	*36.2%*
Aviation Gas	0.0	0.0	0.0	0.0	0.0	*0.0%*	0%	0	0.0	*0.0%*
Jet fuel	0	0	0	0	0.0	*0.0%*	0%	0	0.0	*0.0%*
Kerosene	57.2	45.0	49.1	160.1	0.2	*15.2%*	-1%	51.7	0.1	*11.6%*
Distillate	162	136	147	437	0.4	*41.5%*	4%	240	0.6	*51.7%*
Outboard motor oil	1	1	1	3	0.0	*0.2%*	0%	1	0.0	*0.3%*
LP Gas (esti)	10	0.5	6	16	0.0	*0.2%*	6%	17.9	0.0	*1.5%*
Total	*411*	*314*	*347*	*1,070*	*1.1*	*100.0%*	10%	491.6	1.2	100.0%

Note: no data is available on outboard motor oils so conversions are estimated

Integration of solar energy into the grid will help slow the rate of increased use of diesel and if aggressively pursued may allow 24- hour power with little or no increase in fuel use. Coconut oil for diesel replacement is technically feasible with little modification of the existing engines and if the cost of diesel continues to increase, it may become cost competitive. However, to be cost effective as early as possible, careful planning needs to be carried out to ensure that the collection, production and oil extraction are carried out in the most efficient manner. The logistics of product delivery need to be optimized as transport of personnel and product will be a major portion of the total cost of producing biofuel. With this in mind, the more compact atoll of Atafu may be best for initial trials of biofuel.

2.3.3 GHG Reduction through Aggressive Renewable Energy and Energy Efficiency Measures

Aggressive efforts to improve the efficiency of energy use can result in a reduction of up to 25% of electricity generation fuel within a short time period and 10%-15% of kerosene, petrol and LPG use. If an aggressive programme to develop biofuels is combined with solar installed at a rate of about 10Wp per year, a total GHG reduction of around 31% over the above projections should be possible, meaning that the GHG levels in 2013 would be roughly the same as from 2003.

Table 2.5 summarises the maximum potential savings of 0.405 Gg or 31% of 2013 emissions. Of this 26% is from energy efficiency measures and 74% from renewable energy.

Table 2.5 - Indicative Maximum Fuel Savings & GHG Reductions, 2013

Resource or technology	Potential fuel savings	Potential CO_2 savings (Gg / year)	% of total savings	Comments
Solar and biofuels	120 KL	0.3	74 %	50 % of all ADO (nearly all used for electricity)
Energy efficiency				
Electricity [4]	24 KL	0.03	7 %	10 % of ADO used for electricity
Transport	27 KL	0.075	19 %	15 % of personal boat transport fuel
Total		*0.405*	*100 %*	

Source: mission estimates

[4] About 10% of the volume of fuel used for electricity generation in 2013 could bedisplaced by efficiency measures, that is 10% of 240 KL = 24 KL. However, if 50% of all ADO for electricity is displaced by solar and/or biofuels, then efficiency savings must be adjusted to 12 KL since half of the fuel savings are not emitting GHG.

Figure 2-3 – New Power Station on Fakaofo

Herb Wade 2003

3 Renewable Energy

3.1 Resources

3.1.1 Solar Resource

No long-term solar radiation data was available but past system designs have been based on a value of 5.5 kWhr/m^2/day and their performance has been consistent with that level of solar input. For larger scale systems, the better the understanding of the characteristics of the resource, the better the design can be. Therefore with the installation of the solar power generation system for DoE, it is strongly recommended that a good quality global solarimeter be included as part of the project. Long-term measurements of radiation should be taken at the solar panel tilt angle, not horizontally as is usually the case for meteorological measurements.

Land can be a limiting factor with solar power since peak production is only about 100W per square meter and the average production is considerably less than that. Although there is sufficient land near to the population centres to provide 100% of the foreseeable energy needs, if a single large array is installed there may be a need to remove many trees, an environmentally questionable thing to do. Also there may be land tenure issues solved. Distributing the system over several small arrays should be considered as an option to avoid these problem areas.

3.1.2 Wind Resource

No wind data could be located for Tokelau though an assessment was apparently carried out on Atafu some years ago. Tokelau lies within the trade winds region where weeks of consistent easterly winds may occur. However, long calm periods are also not unusual. Some 65% of all winds in Tokelau are from an easterly direction but speeds are generally modest with less than 5% of surface winds more than 8 m/s and about 50% are 3m/s or less[5].

A particular problem with wind power on atolls is the prevalence of coconut trees. A wind turbine must be well above trees or located in an area far from tall trees. To get above the coconut trees would require a very tall, expensive mast. To find an area far from tall trees either would require an offshore or reef installation or the clearing of a large land area, which on an atoll would represent a significant portion of the total habitable land. While lagoon or reef mounting of a wind machine is technically possible, the cost of submarine cabling and the difficulty of maintenance are problems that largely offset the low capital cost of wind turbines.

3.1.3 Biomass Resource

There has been no actual biomass resource survey. However the unpopulated area of Tokelau is dense with coconut trees and other native plants. The area cleared for personal gardens are just a small percentage of that land and most of the unpopulated islets remain close to their natural state. Its use for energy on a large scale, however, is environmentally unwise and economically impractical due to the high labour and transport cost that would be incurred to get the fuel into a useable form for energy production, and to move it to the generator site.

[5] *Tokelau Telecommunication Network, Power Supply and Equipment Buildings*, UNDP-ITU, 1997 (Bangkok)

The populated areas are well stocked with mostly coconut and breadfruit trees. Biomass is not available beyond a modest amount of waste in the form of coconut husks and shells.

Thermal

On a per-capita basis, there is no shortage of biomass for cooking purposes, although travel to non-inhabited islets for collection might be necessary since the biomass stock on the populated islets of Fale, Atafu and Nukunonu would not be sustainable if a high percentage of the population reverted to using wood for cooking.

Biofuel

Coconut oil as a replacement for diesel fuel is a possible renewable energy source complementary to the use of solar energy for power generation. After the percentage of total energy demand provided by solar PV passes about 70%, the marginal cost for each additional percentage increase goes up rapidly because the size of the array needed to cover long cloudy periods for a specific energy requirement rapidly becomes larger as the required percentage of reliability approaches 100%. Adding coconut oil fuelled diesel generation to handle the last 15-20% of energy needs would be much more economical than attempting 100% renewable energy by solar alone. There is sufficient unpopulated land area for coconut plantations to provide the quantity of coconut oil needed to provide 15%-20% of the electricity demand on each island. However providing that fuel at a price that can compete with imported diesel will be difficult unless the diesel cost rises significantly. The cost of transport from the plantations and the cost of labour for the collection and processing of the coconuts could result in a biofuel price several times that of diesel at 2003 levels particularly on Fakaofo and Nukunonu where the distance to plantations from the village would be much greater than on Atafu.

Biogas

Figure 3-1– Fale Piggery at low tide

Herbert Wade, December 2003

Biogas could be a substitute for all the LPG used in cooking if the approximately 5000 pigs and chickens in Tokelau were concentrated in groups large enough to make biogas generation economical. This would require a major change in the way the animals are housed and raised as well as considerable infrastructure development to install the necessary digesters, gas collectors, compressors, storage tanks and distribution tanks.

On Fale, Fakaofo, the community's pigs are presently concentrated into one area (Figure 3-1), however it is on the reef and the high tide carries away the wastes.

3.1.4 Hydro Resource

There is no hydro resource.

3.1.5 OTEC Resource

Although it is likely that there is a large OTEC resource, the power demand is much too small to warrant its development since the cost per kW goes up rapidly as the size goes down. In any case OTEC is not technically perfected or commercially proven.

3.1.6 Geothermal Resource

There is no known geothermal resource and if there were, its development would not be practical for such a small load.

3.1.7 Wave Energy Resource

Though there have been no measurements of the wave energy resource specifically for Tokelau, it is likely that it is moderate and similar to or slightly less than that measured by satellite in the northern group of the Cook Islands on the order of 20 kW/m. However, until there is a wave energy converter design that has been field proven, found to be economically viable and able to survive the cyclone generated waves, there is no good reason to invest in a wave resource assessment.

3.2 Appropriate Technologies for Development

The technology closest to competing with conventional fuels for electricity production is solar energy. Its use is already well proven in Tokelau and the technology is competitive with small diesel generators in terms of life cycle cost.

Although solar thermal has not been used in Tokelau, where hot water is needed, as in the hospital, hotel or boarding school, solar water heaters are lower in cost than either gas or electricity for heating water. Should there be a demand for piped hot water, solar water heaters should be the first choice.

Although wind power for electricity generation is not likely to be practical, wind power for lagoon transport using traditional or modern sailing boat designs is cost effective for family fishing and lagoon transport when compared with aluminium boats powered by 15-20 Hp outboard engines.

Coconut oil to replace diesel fuel is not presently cost effective but is technically proven and should be considered if a large price increase in diesel occurs or if high priority is given to self-sufficiency in energy supply. It is particularly interesting when combined in a hybrid generation system with solar power.

It is possible to offset most if not all LPG use for cooking through development of biogas from pig and chicken wastes. However its cost effectiveness depends strongly on labour costs and on solving the requirement for concentrating and housing the animals in a manner that makes waste collection easy.

4 RENEWABLE ENERGY EXPERIENCE

4.1 Historical

The earliest use of renewable energy for electrical power appears to have been in 1984 when photovoltaics was installed to provide power to the high frequency (HF) single side band communications radio on each atoll. Available records do not show the size of the PV arrays but about 50 Wp of panel is indicated. Although batteries were changed many times, the panels were not changed. They were examined in the 1990s and although some delamination and corrosion of terminals was found, in general the panels remained operational. In 1998 it was estimated that the PV arrays could continue to operate for five years or more. The HF radios are no longer operational, having been replaced by satellite communications through TeleTok.

4.2 Current Applications

4.2.1 TeleTok

Figure 4-1 - Fakaofo TeleTok Installation

Gerhard Zieroth (2003)

Each atoll has a TeleTok satellite station partially powered by photovoltaics that was installed in 2000. The continuous load is about 1.7 kW run from a 56 kWh at 48V battery bank (Absolyte IIP 3-90A23 batteries) providing an effective time of operation from full charge to 50% discharge of about 16 hours in an emergency. Design value for battery operation is for only three hours (10% depth of discharge) so the night -time use requires external power even under the best solar conditions. Charging is either by small independent diesel generator at TeleTok, the power grid or 5 kWp of solar panels.

Table 4-1 – TeleTok PV system performance

Location	Output kWh/year	Net Output (kWh/kW/day
Atafu	6889	3.5
Fakaofo	4528	2.3
Nukunonu	Similar to Fakaofo	2.3

Source – *Tokelau Telecommunications Network, Power Supply and Equipment Buildings*, ITU, NDP, 1997

Equipment installed on each atoll included four arrays of 16 polycrystalline Solarex VLX80 (80Wp) solar panels totalling 5,120 Wp of capacity, three Trace C-40 three stage controllers rated at 40 Amperes, two 48V battery banks made up of Absolyte 2P-3-90A23 batteries totalling 1,390 Ah at C_{100}. An AC powered battery charger was also included to maintain battery charge from the grid or from a stand-alone backup generator.

The output of the systems (Table 1-1) was reported by Mr. Peter McQuarrie for the TeleTok stations during their first year of operation. Based on this data, approximately 45% of the power can be provided by photovoltaics if design conditions of service are maintained.

4.2.2 USP

The University of the South Pacific facility on Atafu has its communication links powered by photovoltaics in order to have a reliable 24 hours a day communications capability. A 6 kWp solar array was installed at the USP extension facility in 1998. A 50V battery bank capable of 168 kWh of storage was provided with an inverter to deliver AC power. The storage capacity is sufficient to operate the station for about 80 hours if a 50% discharge of the batteries is allowed. Charging can be either by the PV array or from the AC grid. Operating data could not be obtained but the system appears to be operational although it is known that there was an early inverter failure and with the system depending on only that one inverter there was extended down time.

Figure 4-2 – USP Solar Installation Atafu

Thomas Jensen

4.2.3 Individuals

A few households have purchased PV panels and batteries to operate lights during the time when the generator is not operating but there has been no attempt to draw lessons learned from their experiences.

4.3 Lessons Learned from the Tokelau PV Experience

- Solarpanels can survive for a decade or more in Tokelau with minimal degradation
- Satisfactory reliability can be achieved through high quality of design and component specification.
- Spares of critical components, particularly electronic devices sensitive to the environmental conditions in Tokelau, should be maintained on island.

4.4 Confirmed Future Projects

In 2002 UNDP/UNESCO, after extensive discussions with Tokelau, New Zealand Aid and the New Zealand Ministry of Foreign Affairs and Trade, agreed to write a proposal for funding, for the use of solar energy to supplement the powergrid in Tokelau. The installation would be the first step in Tokelau's plan of completely divorcing itself from fossil fuel supply and returning to a self-sustaining energy economy.

After several design iterations with input from Tokelau, UNDP and external experts in Pacific solar implementation, tender responses for component supply were sought in early 2004 and a selection will be made by mid-year. Though the original intent was to develop solar energy equally on each atoll, the budget was too limited to permit significant impact unless concentrated in one location. Fakaofo has been selected for the pilot installation. The basic design had not been fixed at the time of writing but is expected to be 10kWp of solar panels with battery storage feeding a 30-kVA three-phase inverter. A major problem with hybrid installations in other countries has been the maintenance of the complex electronics interface needed to feed power into the grid simultaneously with diesel generation. The Tokelau installation is expected to avoid that complexity by using the solar system to feed a section of the Fenuafala grid independently as long as sufficient battery capacity is available then manually switch that section to diesel power until battery recharging is complete. Since the long range vision is for solar power to provide the principal energy source for the grid, this approach is consistent with expected patterns of future use of solar and also avoids the technical complexity that has been a problem elsewhere.

4.5 Proposed Renewable Energy Projects

The PIREP team recommends the following actions for further development of renewable energy in Tokelau:

Wind and solar resource assessment. For each atoll, a wind resource assessment on the reef well away from trees and a similar assessment near the populated area are needed for a full understanding of the wind regime. A solar resource assessment using good quality measuring instruments tilted at the same angle used for PV panel installation also is needed to provide important design information regarding the quantity and characteristics of the solar resource.

Design of the appropriate process for development of biofuel for the future. A series of operational scenarios with various production locations and transport options would be developed including a sensitivity analysis for the factors of labour, transport, land use cost and equipment cost so an optimal production process consistent with Tokelau social and environmental conditions can be prepared.

Master plan to meet the 100% renewable energy goal for each atoll. It is unlikely that the optimum approach to 100% self-sufficiency in energy will be the same for all atolls. Individual social, physical and environmental conditions should be considered and a long-range energy development plan created specific for each atoll.

Incremental increase in PV capacity for power generation. Solar will remain the basis for renewable energy development for the immediate future and expansion projects should be initiated right away if the goal of energy self sufficiency is to be reached.

5 Barriers to Development and Commercialization

The identification of barriers to the development and commercialisation of renewable energy for Tokelau was the subject of a S.W.O.T. workshop held on Fakaofo on 9 December, 2003. Additional information regarding the barriers to renewable energy development was gathered by the PIREP team. Tokelau has almost no experience with renewable energy other than traditional uses of biomass but has placed achieving energy independence as a cornerstone of its energy policy.

Though the barriers are categorised into similar groups, the placement is somewhat arbitrary. It is recognised that many barriers have implications in several categories.

5.1 Fiscal and Financial Barriers

The primary barrier remains the lower financial cost and greater ease of use of petroleum. Introducing a less convenient and higher cost energy source to replace petroleum will require both additional money and the willingness of the Tokelaun people to accept the problems associated with large scale use of the renewable energy resources.

Access to donor funding. As a New Zealand dependency, Tokelau has limited access to non-New Zealand capital funding for renewables. This somewhat limits the opportunities for funding and access to European, American and Japanese expertise.

The cost of access is high. There is no airport on Tokelau. All goods arrive from Apia by ship, normally twice a month. Shipping cost are high as is the cost of travel between islands particularly if a visit of more than a few hours is needed. This means a wait of more than a week to access the next ship. This makes it costly and difficult for the DoE to support the *taupulega* on all three islands.

5.2 Legislative, Regulatory and Policy Barriers

Since Tokelau is now approving a national energy policy and strategy, policy and legislation are not seen as barriers.

5.3 Institutional Barriers

Throughout the Pacific, one of the main points of failure in renewable energy projects have been institutions unable to provide sustainable operations. Each renewable energy source needs proper technical and institutional structures for receiving payments, providing service and equipment maintenance plus installation of new components. Some renewable energy sources, notably biofuels and biomass, also include structure to bring together large numbers of independent fuel producers together so the energy source is continuously available at a minimum cost.

Insufficient technically trained personnel. Limited human resources make it difficult to achieve the level of staffing necessary for the provision of reliable technical services. Because of the isolation of each atoll, the effective capacity is that of the individual atoll, and not a collective figure. That means all services must be organized and carried out from a group of about 250 working age adults on each atoll, none of whom are likely to have had any technical training.

Lack of technical training facilities. No technical training facilities are available on Tokelau. Most training available overseas has only marginal relevance to Tokelau's situation.

Ease of migration to New Zealand. There are strong incentives for technically trained personnel to migrate to New Zealand causing a continuing turnover of personnel and a need for training.

Land issues. Land issues are complicated and landowners are often not resident in Tokelau but in New Zealand making negotiations difficult and costly. Reaching the goal of 100% renewable energy will be difficult if biofuels cannot be a part of the renewable energy used. Since biofuels require coordinated delivery of large numbers of coconuts on a schedule, land issues become a barrier.

5.4 Technical Barriers

Solar, wind, biofuels and possibly biogas are the technologies most likely to be used in Tokelau and all are mature technologies. However the equipment needs to be robust, reliable and able to handle the extremes of tropical marine climates.

Difficult environment for electrical and mechanical equipment. The tropical marine environment of Tokelau is one of the most difficult for mechanical and electronic equipment. Obtaining equipment suitable for installation is difficult and expensive. Electronic control systems, and DC to AC converters are vulnerable and must be designed specifically to handle the salt laden air, high ambient temperature and moist conditions.

Energy Efficiency Issues. Poor energy efficiency is a block to achieving a larger percentage of renewable energy nationally. The relatively high cost of developing renewable energy resources to replace petroleum makes energy efficiency critical to renewable energy development. Reaching 100% renewable energy will cost less and occur more rapidly if the significant amount of energy being wasted can be reigned in.

Spare parts access. Infrequent access and expensive communications make it difficult to obtain technical support from manufacturers and incurs a long time delay for factory repairs the wait for ordered parts. This makes it necessary to maintain a larger than normal spare parts stock if reliability is to be achieved.

5.5 Other Barriers

Extended, narrow landmass. The geography of the atolls makes access to biomass or biofuel plantations relatively expensive compared to that for a single landmass having road based transport between the source and use of biomass.

Severe weather. Cyclones are infrequent but there is a definite risk of damage to exposed infrastructure such as solar panels or wind machines. Following a cyclone, productivity of coconut trees is reduced for up to six months..

5.6 Market Barriers

High energy use per household. High electricity demand due to the use of freezers and refrigerators, plus a highly subsidised consumer rate makes it difficult and expensive to convert to renewable energy.

Import dependence. Tokelau is virtually 100% dependent on the external supply of products and services, having moved during the 20th century from an essentially self-sustaining economy to one nearly totally reliant on important goods. For renewable energy to be successful, a reversal of that position is required. Social, economic and political adjustments need to be made.

5.7 Informational and Public Awareness Barriers

For renewable energy technology to be accepted, it is important that people at all levels understand its benefits and its problems. People need to become comfortable with the idea of replacing fossil fuels with renewable technologies. Various public awareness programmes have been established in the region but Tokelau has none presently in place.

Limited knowledge of renewable energy at high levels of government. Tokelau's size means that there is only a small support staff for even top level decision makers. For decision makers in Tokelau to include renewable energy appropriately in energy development plans, they must have a professional sources of information and advice. This overlaps into promoting public information programmes

Limited public awareness of energy efficiency and renewable energy options. The most cost effective approach to reducing petroleum use is clearly through energy efficiency improvements. However, there is little public knowledge of demand side management techniques or of energy efficiency improvement in general. *Taupulega* are not fully aware of the concept of supply side efficiency. Solar PV, biogas, biofuels and wind power are not commonly known as potential renewable energy resources. . If energy efficiency and renewable energy are to become substitutes for petroleum, an awareness of their capabilities – and shortcomings – needs to be improved.

Language Barrier. Although English is commonly spoken as a second language, a large number of people in Tokelau, particularly older persons, find it difficult to communicate extensively in this language. This limits the utility of information resources, including those from New Zealand. If public awareness programmes are going to work, translations into the local dialect is needed.

6 Implementation and Capacity Development Needs

Capacity building is needed to backup any shortcomings in the work of the National Government and the *taupulegas* in putting policies in place and the logistics of trying to make mechanical and electrical systems run efficiently in a hostile environment. Although projects can be developed to address specific regional issues they are sometimes to broad and general. Economic and Social Commission to Asia and the Pacific (ESCAP) is developing a regional training plan. If undertaken the planwill provide most of Tokelau's development needs.

6.1 Categories for capacity development

6.1.1 Petroleum

As long as drum based shipments are used, there is no need for externally skills training in handling petroleum fuels. If bulk storage is developed, training in safety, maintenance and storage management will be essential. Currently the small volumes of petroleum purchased and the existing tender processes being used appear adequate.

6.1.2 Electricity

Maintaining technical capacity is a major problem for Tokelau. Training for DoE technical staff and *taupulega* management staff will be a frequent requirement on Tokelau. The expatriate head of the DoE is in the process of developing a training plan and manuals for the operation and maintenance of the power systems on all three islands. This can provide the base for future capacity building and maintenance. Language barriers cause difficulties for both locals and overseas trainers who are expensive to hire. Videos in Tokelauan on how to develop comprehensive power system operators and maintenance training should be considered as an alternative to using overseas trainers and translators.

6.1.3 Renewables

As the use of renewable energy expands, there will be an increasing need for training of maintenance people who can speak the local language. Again, a video or computerized teaching programmes may provide better and cheaper training for technicians than overseas trainers arriving on island or locals travelling overseas for upskilling.

At least one DoE employee will need to receive advanced training in system maintenance to support the operators and technicians on each island. That will require either the DoE staff person to travel to a training venue off island or a trainer will need to come to Tokelau to provide training. Obviously it is important the training is relevant to Tokelau's specific types of renewable energy systems. .

6.1.4 Energy Efficiency

Senior technical staff in the power sector should be given training in supply side efficiency, improvement and maintenance, plus demand side management relevant to the local situation.

In 2003 the *ulu* expressed strong interest in working out a system where only high efficiency appliances that can withstand Tokelaun conditions would be imported.

Assistance in evaluating available appliances. Appliances available for import need to be evaluated for energy efficiency and compliance and resistance to corrosion. It is noted that the opening of supply routes from Japan via Samoa may be necessary since size, energy efficiency and construction of Japanese appliances maybe better suited for Tokelau as opposed to goods from New Zealand or Australia.

6.2 Fiscal and Financial Barriers

Project development support. Local staff need training and help with designing project documentation acceptable by financing institutions. As part of regional capacity building efforts, specific programmes in project development, document preparation, economic analysis, and interfacing with international finance agencies should be developed and delivered. They need to focus not only on the DoE, but *taupulega* staff plus those individuals in Tokelau responsible for project proposals and documentation.

6.3 Legislative, Regulatory and Policy Barriers

Energy Strategy Assistance. The National Energy Policy is expected to go into effect by 2005. Although specific strategies are proposed under the policy, assistance to Tokelau in developing further strategies will be useful. The PIEPSAP will not be available to Tokelau as it is available to African Caribbean Pacific (ACP) countries only.

Regulatory Systems Development. The DoE has as one of its important functions the development of standards and regulations for energy. Although a basic set of safety, maintenance and operational standards/guidelines has been developed for diesel generation, assistance will be needed to develop equivalent standards/guidelines for renewable energy implementation. Also assistance in developing an appropriate structure within DoE for enforcement of standards and regulations will be needed. This assistance may be directly available from New Zealand but support from regional programmes should also be sought.

6.4 Institutional Barriers

Training of DoE Personnel. It is common for energy office personnel to move on after a few years. So training for energy officers is essential to provide continued capacity building so the technical and administrative tasks are properly managed. However there is no training available in Tokelau for the technical component of this work. Training needs to be made available within a few months delay after a new employee comes on board. This implies that the training will need to be external and regional in nature since a training programme of this type cannot be sustained on the basis of the needs of Tokelau alone. The regional training concept being developed by ESCAP in late 2004 should resolve this issue.

Development of a biofuel delivery institution. If biofuel is to be a cost effective replacement for diesel, an institutional structure will have to be developed that will (a) enable a large number of small coconut growers to pool their resources; (b) ensure that each grower receives proper compensation for their efforts; (c) minimize the labour and transport component of the biofuel production process; (d) manage small biofuel facilities on each atoll to avoid the problems and expense of shipping; (e) ensure that a fuel supply is of consistent quality is available when needed. This initiative needs the experience of actual biofuel suppliers. Funding is necessary to bring together persons from other countries with commercial biofuel experience e.g. Vanuatu, or the Philippines to work with Tokelau to design an institutional structure that specifically fits its needs. Since this problem is common to several countries, a regional conference plus a follow up outreach programme appears appropriate.

6.5 Technical Barriers

Training of *Taupulega* technical staff. Although there is experience with diesel power systems, hybrid systems are new and considerably more complex. DoE technical staff will need to know the design parameters and characteristics of the various types of hybrid systems possible for Tokelau. They should also be able to judge whether or not externally developed designs are appropriate or not. Department training in the operation and maintenance of the systems will have to be developed so these skills can be passed on to the *taupulega* operating and maintenance personnel. Because a local language will have to be used for training and because the equipment used in Tokelau is probably unique to the region, a customised programme is required.

Development of standards and certifications for RETs. Although there are international standards already developed or being developed for RETs, they are generic and must be customized to suit the local situation. Because equipment must be manufactured to survive under harsh conditions, this should be reflected either as purchasing guidelines or, better, as actual standards for the provision of RET equipment. Unlike the training programme, a standards and certification development programme needs to be completed only at several year intervals. As this is a regional issue (with similar problems facing Kiribati, Tokelau, Republic of the Marshall Islands and the Federated States of Micronesia), a programme that suits this purpose is ideal..

Resource Surveys. For the most cost effective renewable energy development, it is important that accurate knowledge of resource volume on site is available. For example wind power is site specific, so technical expertise is needed to judge where the best locations are and in drafting a wind energy assessment. Similarly for biofuel where knowledge of the location and productivity levels of coconut trees is vital.

Most of the work in these surveys can be carried out by locals, though assistance will be needed with survey design and site location. Analysis of the results will also require outside help, preferably in the form of on-the-job training for local energy personnel so the process can be repeated in the future. . Several countries face analysis problems with biofuel, solar and wind energy. Resource surveys would be a good candidate for a regional programme.

6.6 Market Barriers

The basic problem of the market being too small and widespread to support private development of renewable energy resources, cannot be addressed by capacity development measures.

6.7 Informational and Public Awareness Barriers

Decision maker information delivery. Through in country programmes, sessions at international assemblies of decision makers, PPA annual meetings, SOPAC meetings, Forum meetings and other venues, information needs to be provided so decision makers are aware of the most appropriate technologies and problem that needs to be avoided. DoE staff and Council of Faipule advisory staff should receive specific information packages and where possible, actual training on how renewable energy technology can aid national development, as well as the best approaches to energy strategies, efficiency and renewable methods. This is a need common to most of the smaller PICs and can be developed into a regional programme.

Public information programmes. Although solar energy for home electrification is well known in Tokelau, there is little awareness about biofuel, biogas, wind power or hybrid systems. As awareness is needed for most PICs, public information materials can be developed regionally, then delivered to countries along with short term training and advice on their proper delivery.

7 Large Scale Renewable Energy Use

The goal of 100% renewable energy for Tokelau is possible. . To do so will require the use of solar PV, solar thermal energy, biomass, biogas and biofuels. It also will require major expenditures on energy development and a commitment on the part of the populace and leadership to make the transition.

7.1 Solar

7.1.1 Land issues for large scale use

Land can be a limiting factor for large-scale solar energy use in Tokelau. A $1m^2$ PV panel can provide approximately 500 Wh/day in Tokelau. To replace a diesel generator with an average output of 40kW for 24-hours would require around 2000 m^2 of solar panels in an unshaded location. The ground area for such an array would be at least 4000 m^2 due to the requirement for access to all panels for servicing and the area required by the mounting system. Adding the building required for the battery storage system and power conditioning equipment, the total land area needed would be around 5000 m^2 or a square of about 70m per side. The area around the array would need to be cleared of trees for at least 30 metres from the array increasing the total clear area to a square about 100m per side, about the size of a football field. While that is not impossible to overcome, the dense population of the inhabited islets and the complex land tenure issues make the final solution problematic. A common answer for adding solar to an existing conventional power system is to distribute the solar as 4-10kW modules spread over the grid, when solar provides more than about 25% of total energy production, there are technical problems that have yet to be resolved. While a practical solution in the future is likely, a dispersed solar system is not an acceptable option.

7.1.2 Battery disposal issues

If largescale solar implementation is carried out, similar size energy storage will be essential. As lead acid batteries are likely to be used for storage the power authority will need to make arrangements for their return to the manufacturer for recycling about every 10- years. The battery disposal problems associated with solar home systems involving large numbers of small batteries will not exist in Tokelau, since the battery storage will be an industrial scale system at the larger solar sites. As high quality industrial batteries will be used, their life span should be at least 10- years. along with recycling very good. Expired or malfunctioning batteries can be stored indefinitely indoors without losing their recycling quality.

7.1.3 Solar Thermal Energy

There is little demand for hot water for domestic, commercial or government although solar water heating is clearly the most economic approach. It is reasonable to assume that all future water heating needs can be met by solar water heaters.

7.1.4 Fuel replacement potential

While in theory it is possible to provide total electricity generation using solar power, the costs per unit above the 70% mark is uneconomic..

7.2 Biofuel

By far the primary benefit of large scale biofuel production would be less dependence on imported fuel sources and local control of the fuel prices. However there is a negative side to large scale biofuel development.

7.2.1 Land development issues associated with large scale biofuel utilisation

Large scale biofuel use implies first developing an equitable method of developing the plantations and compensating land owners, then developing a labour efficient process for the gathering, transport and processing of coconuts grown on unpopulated islets. Since the islets are long and narrow, as biofuel volume requirements go up, the transport needs increase along with the need to develop roads and inter islet transport capability. So for biofuel to be the lowest possible cost at the location, careful system design for the whole process, from tree to end use, is necessary. Location of the plantations, copra extraction and oil expellers needs to be considered. Labour hire, personnel and product transport have to be taken into account, to determine the most economic approach to delivery of biofuel to the power plant.

7.2.2 Social and economic issues

In most PICs, biofuels represent a rural development opportunity whereby rural communities can increase their cash incomes and take advantage of unused or underutilised resources. In the case of Tokelau, there is no rural/urban distinction so rural development as such is meaningless. There is no unemployment in Tokelau so if large scale biofuel development is undertaken, the village labour force will have to increase their workload to include both the tasks already considered necessary for the workforce to accomplish and the new tasks associated with biofuel preparation. This could create social tension and cause the loss of some public services that seen as less important than fuel production.

Many landowners who will benefit from coconut sales for fuel, live in New Zealand, so a cash outflow from Tokelau to urban New Zealand can be expected. Although that will reduce the benefit to the island economy, it can be argued that this at least the monies will go to other Tokelauans.

7.2.3 Fuel replacement capacity

If the above problems can be resolved and if the cost of conventional fuel continues to rise, it is in theory possible for all existing diesel fuel to be replaced by locally produced biofuels.

7.3 Biogas

7.3.1 Land use and social issues

Biogas production at the scale needed to replace LPG use for cooking will require concentrating the housing of livestock to allow effective gas production. This will introduce social issues relating to land use, the correlation between ownership of animals and ownership of gas production. A equitable decision by all parties needs to be made to pay land and animal owners a fair price for the volumeof gas produced.

7.3.2 Economic issues

Obviously there will be a reduction in the need to import LPG and kerosene for cooking and. Except possibly for some land compensation that may have to be paid to land owners residing in New Zealand, the cash savings will remain in the local economy.

The gas must either be collected and piped under pressure to the houses or compressed into cylinders and provided to houses as needed. This implies some technical infrastructure requirements with associated employment and skills improvement.

7.3.3 Fuel replacement capacity

If the above issues can be solved, the present population of animals in Tokelau is sufficient to replace the modest use of LPG.

7.4 Biomass

Biomass remains a viable resource for energy production through burning and gasification. The resource is sufficient to provide for all cooking needs. No other uses for biomass are envisioned at this time other than the existing very small scale use for drying.

7.5 GHG Reduction through Renewable Energy Use

As noted in section 2.3.3, aggressive implementation of renewable energy and energy efficiency measures over the ten year period could result in a 2013 GHG reduction of as much as 35%, allowing the projected increases in energy use over the next ten years to take place with no increase in of greenhouse gas emissions. The goal of 100% renewable energy for Tokelau cannot be met by 2013 without a level of funding unlikely to be achieved, but if the process for biofuel development commences immediately and investment in solar energy continues at a rate of about 10kWp per year, the 100% renewable energy goal probably can be met within 15-years.

Much of the 35% reduction in projected GHG over the next 10-years is due to energy efficiency measures, that can be accomplished quickly and at modest cost. Developing large scale renewable energy use will be slow and relatively expensive.

8 Capacity Development Co-Financing Opportunities

As a dependency of New Zealand, Tokelau has limited opportunities for financing renewable energy and energy efficiency development from other outside sources. However, UNDP and GEF co-financing with New Zealand, particularly as regards capacity development and non-hardware implementation, may be possible.

With their small scale applications, Tokelau will not be able to support advanced technical personnel such as graduate engineers specializing in renewable energy development. Even at the senior technician level, only one person is needed, with most of the requirement for training at the operator and maintenance level. Therefore it is unlikely that regional programmes that generalize training to fit a wide range of country needs will provide much benefit to Tokelau. Further, many personnel needing training have limited English skills . For training to be effective, it will need to focus on specific types of local installations. For these reasons many capacity building efforts need to be custom designed for Tokelau. This makes integration into regional capacity building programmes difficult.

8.1 Co-financing opportunities

As noted above, the requirements for non-hardware support for Tokelau will be quite different from those of the other PICs; and on such a small scale that it is likely to be difficult for a regional programme to justify a co-financing arrangements with local renewable energy projects.

In any case, there are no assured projects known to be under development in the same time frame as PIREP. The UNDP/UNESCO solar electricity project for Fakaofo is already past the tender stage and will probably be operational before a follow on to PIREP commences so it cannot be considered for co-financing. There are no other energy projects in the pipeline, though it is reasonable to expect the long term policy of the government to work toward attaining complete energy independence will result in future renewable energy projects.

9 ENERGY EFFICIENCY OPPORTUNITIES

9.1 Petroleum Use

Improving efficient energy use is the fastest and least costly approach to reducing fuel import costs GHG emissions. If 100% energy self-sufficiency is to be achieved at an acceptable cost and a reasonable time, better efficiency levels is vital. Wasting energy use is a major barrier to the rapid achievement of this goal.

With petrol only used for outboard engines, the use of boats is the only area where an improvement in the efficiency of petrol use can be gained. Outboard motor sizes may be regulated to prevent their gradual "power creep" and the increasing use of petrol per trip that has been observed in other Pacific Island countries. Petrol rationing has been effective a effective control on Fakaofo and in limiting the use of boats for higher priority trips. A method of rapidly increasing the price of petrol when more than a basic amount is purchased during any given period could provide an incentive to use boats more efficiently while avoiding the need for strict rationing. Rekindling the interest in sail power for subsistence fishing could greatly reduce the use of petrol for lagoon fishing.

A bicycle/footpath on the reef connecting Fale with Fenuafala has been considered. This would reduce the boat traffic between the two villages significantly even though initial costs would be high.

Consideration should be given to a scheduled diesel powered water taxi service between Fale and Fenuafala to improve passenger transport efficiency between the two villages.

Diesel for transport is almost entirely used by the *M.V. Tokelau* for shipping to and from Samoa. Fuel efficiency should be a major factor in choosing the replacement for the ageing ship, since it is expected that will be an increasing cost for the future as fuel prices rise. Programming of voyages and the manner of utilization of the vessel also have a major impact on fuel use.

A programme for ongoing training of maintenance personnel, and to provide the necessary tools and manuals for maintaining optimum fuel efficiency on the *M.V. Tokelau* and its successor would be of value.

9.2 Electricity Supply

The completion of the upgrade project with new generators and mostly new distribution should result in a power system that has few immediate needs for improvement. . To maintain that, the procedures that DoE is instituting to continually monitor technical losses and make corrections where problems are found should be carefully followed on each atoll.

9.3 Electricity Use

There are many opportunities for increasing the power efficiency. . Private freezer use appears to be very inefficient, with low value products being kept for long periods at high cost or using freezers that are larger thannecessary. Establishing a community freezer facility with individual, lockable freezing chambers for rent to families is a more efficient use of energy resources for preserving food is a possible solution. This approach would require designing freezer machinery that would ensure that a compressor or parts failure would not cause the loss of all capability.

Imports of appliances should consider energy efficiency and operational life as well as cost. Incentives or mandated energy standards need to be set to improve the basic efficiency of imported appliances. Choosing appliances that are constructed of materials with low sensitivity to the local environment will not only increase their useful life, it will also avoid much of the energy efficiency decrease over time, that has been common with many appliances.

Improvements in lighting efficiency can be made. Without reducing output, energy requirements for lighting can be reduced by up to 30% for existing fluorescent lighting and at least 75% for incandescent lights. High efficiency electronic ballast fluorescent lights can replace the choke ballast units being used. Compact fluorescents can replace incandescent lights. Plastic or aluminium constructed fixtures should be used for longer life.

Use patterns are not optimal and can be significantly improved. For example, both large churches on Fakaofo were seen to leave all their lights on continuously, day and night. With over 1000 Watts of unmetered lighting, the use of these lights is a major waste of fuel, a cost the community need to avoid. All consumers should be metered and required to pay the established tariff for energy use.

9.4 Fuel wood

There is no significant wood fuel use that can be addressed. There also is no present or impending scarcity of this fuel.

10 Annexes

Annex A – Persons Contacted by the Local and International Consultants

Kolouei O'Brien	*Ulu* o Tokelau (Head of Government)
Falani Aukuso	General Manager, Office of the Council for the Ongoing Government of Tokelau
Thomas Lynge Jensen	Sustainable Energy Advisor for UNDP and UNESCO Apia and Manager for the Tokelau PV Project
Afega Gaualofa	Office of the Council of Faipule
Lui Pedro	Supervisor Maintenance project
John Bosco	Department of Energy
Malia Talaga	Womens Association
Helepa Vili	Womens Association
Tautala Matini	Womens Association
Ake Heo	Womens Association
Patemo Tefono	Mens Association
Seanoa Motusia	Mens Association
Simona Mei	Mens Association
Logotahi Vili	Mens Association
Foliga Pereira	Youth Association
Samu P.	Youth Association
Lemuelu Falima	Youth Association
Torisse Liu	Youth Association
Tulafono Penehe	Youth Association

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